Coupled Atmosphere-Ocean Modeling Program Using Movable Nested Grid Techniques

Isaac Ginis and Lewis M. Rothstein
Graduate School of Oceanography
University of Rhode Island
Narragansett RI 02882
Phone: (401) 874-6484 and (401) 874-6517
Fax: (401) 874-6728
Email: iginis@gso.uri.edu and lrothstein@gso.uri.edu

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LONG-TERM GOAL

Our long term fundamental goals are 1) to develop a movable multiply nested mesh ocean model and investigate its application for air-sea interaction studies on the mesoscale, 2) to study coupled air-sea processes at very high wind speeds, 3) to investigate the capability of coupled tropical cyclone - ocean models for improving predictions of the ocean response and tropical cyclone evolution, and 4) to develop model initialization and data assimilation techniques for short and medium range coupled air-sea predictions.

OBJECTIVES

The specific objectives of this project are to: (i) further develop the URI movable nested-grid ocean model and its coupling with a tropical cyclone model; (ii) test the new GFDN/URI coupled tropical cyclone model for real-case tropical cyclone-ocean simulations in the western Pacific; (iii) conduct process-oriented studies of air-sea-land interactions in tropical cyclones.

APPROACH

The tools for this work are high-resolution ocean and tropical cyclone models used in either coupled or uncoupled configurations. The ocean model is the URI movable nested grid ocean model (Ginis et al. 1998, Rowley and Ginis 1999). The major feature of the model is its multiply nested, movable mesh configuration, which is capable of depicting the ocean dynamics with high resolution in the region of interest and simultaneously resolving the large scale circulation.

We also employ one of the premier tropical cyclone forecast systems, the GFDL model, which is the official operational hurricane prediction model at the National Weather Service. This model (known as the GFDN) is also run operationally for the western Pacific at FNMOC.

WORK COMPLETED

We have completed our objective to develop a movable nested grid ocean model. After careful testing of all model components we are confident that the model is now fully suited for both open ocean and

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14. ABSTRACT
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near-coastal studies. The usefulness and robustness of the developed model will be determined from an accumulation of actual performance experience. Efforts are currently underway to apply the model to various ocean and coupled atmosphere/ocean simulations. In particular, the model has been applied for coastal ocean circulation studies in the Gulf of Mexico and coupled tropical cyclone-ocean predictions.

The coupled GFDL/URI nested grid model has been tested for real tropical cyclones in the Atlantic and Pacific basins using the 2000 and 2001 data. For the western Pacific tropical cyclones the data were provided by FNMOC.

We have conducted a case study of the ocean surface wave response to Hurricane Bonnie (1998) using the NCEP WAVEWATCH III surface wave model. The results of the numerical simulations were compared with the wave data obtained through a joint effort between the NASA/Goddard Space Flight Center and NOAA /Hurricane Research Division and moored buoys and C-Man stations of National Data Buoy Center. The wave model is presently being implemented in the GFDL/URI coupled tropical cyclone model.

We have also conducted a numerical study of the ocean salinity response to tropical cyclones in the western Pacific. This study combined idealized simulations aiming to better understand the effect of rainfall on the salinity changes in the mixed layer in tropical cyclone conditions with real case simulations of Typhoon Yancy (1990) and Dot(1990) for which observational data were available.

RESULTS

We highlight here only some of the results of the completed and ongoing work.

Examples of the nested model capabilities for simulation coastal circulation in the presence of high resolution topographic features are shown in Fig. 1. In a set of idealized experiments we simulate the propagation of Kelvin waves along a northern hemisphere shelf. The waves are generated by a localized three degree temperature anomaly introduced on the shelf near the northern edge of the basin. The shelf is characterized by a steep drop off in bathymetry from a minimum depth of 200m to a maximum of 4500m. This shelf is interrupted by a narrow canyon about halfway up the basin. In experiment one, a 32km uniform resolution is used. At this resolution, the narrow canyon is poorly resolved. In experiment two, the uniform resolution is increased to 16km, substantially improving the representation of the canyon. Finally, in experiment three, a nested grid configuration is introduced, where the outer grid resolution is 32km and the inner grid resolution is 16km. The model is designed so that the inner grid follows the pronounced mode 2 Kelvin wave as is propagates away from the anomaly region. Animations of these results may be found at our website, http://www.po.gso.uri.edu/Numerical/nested/nested.html

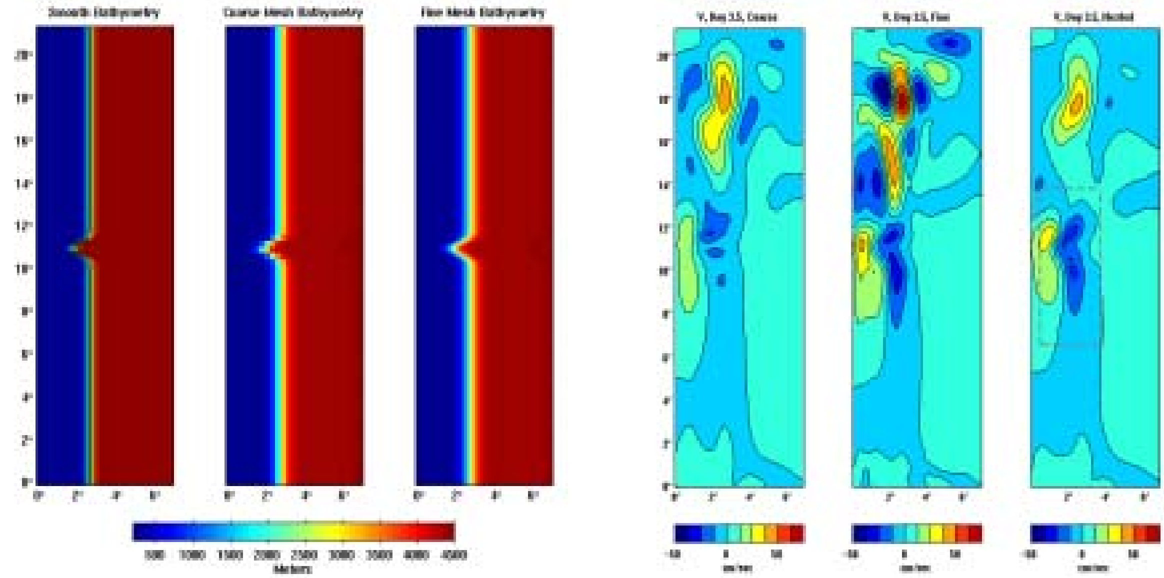

Figure 1. Left panel: The bathymetry used in idealized experiment with a narrow canyon in the middle for differing resolutions. Right panel: Meridional velocity fields for coarse, fine, and nested grid experiments at the time with the second Kelvin wave mode pass over the canyon. It is evident that that the velocity field is well resolved in the inner mesh of the nested model similar to the fine mesh experiment.

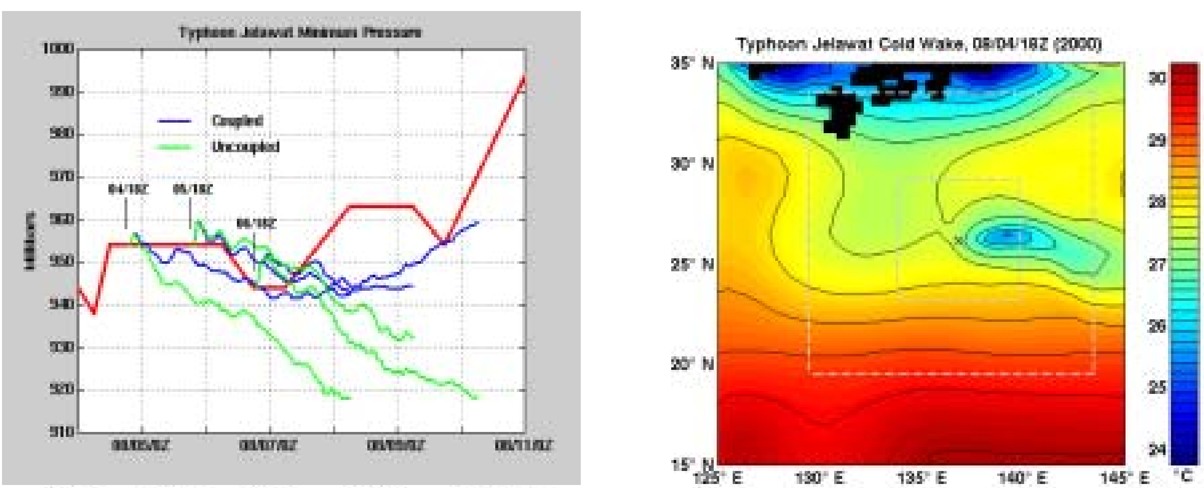

Figure 2. Forecasts of Typhoon Jelawat (2001) in the western Pacific using the coupled GFDL/URI nested grid model. Left panel: Minimum sea level pressure (red – observed, green – uncoupled model, blued – coupled model). Right panel: the simulated sea surface temperature response in one of the forecasts (dashed lines indicate the location of the two inner meshes).

The coupled GFDL/URI nested grid model has been tested for more 20 cases of western Pacific tropical cyclones. It clearly demonstrates the ocean coupling plays a very important role in predicting tropical cyclone intensity, similar to what we observe in the Atlantic basin. Therefore, future application of the coupled model for operational forecasting in the Pacific basin is warranted. Figure 2 illustrates the model performance for 3 forecasts of Typhoon Jelawat in 2001. Animations of the ocean sea surface temperature response in the nested model may be found at our website, http://www.po.gso.uri.edu/Numerical/nested/nested.html .

The NCEP WAVEWATCH surface wave model demonstrates a good skill in reproducing a spatial distributions and magnitudes of the wave heights, directional wave spectra and peak wave direction and frequency in Hurricane Bonnie (1998) for both open ocean and landfall conditions. Figure 3 shows the comparison between the observed and simulated directional spectra.

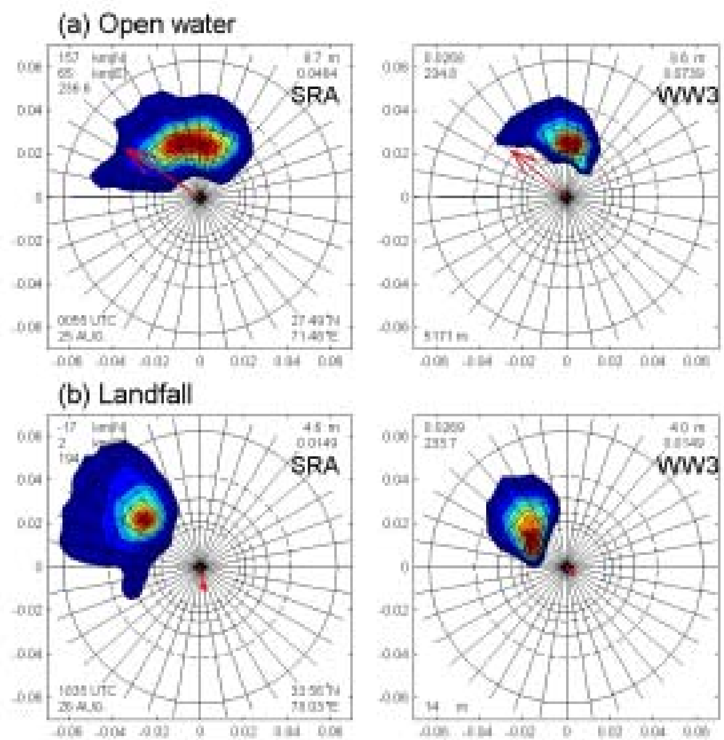

Figure 3. SRA directional wave spectra and WAVEWATCH spectra for (a) open water (0055 UTC on 25 August) and (b) landfall (1835 UTC on 26 August). The dashed circles (outer to inner) correspond to wavelengths of 150m, 250m, and 350m. The solid circles indicate wavelengths of 100m, 200m, and 300m. The thick arrows extend in the downwind direction a distance proportional to the HRD surface wind vectors and the model input wind vectors at that spectral location. A wind speed of 30 ms^{-1} corresponds to a length of 0.03 radian m^{-1}. The location north and east of the eye in km is indicated in the upper left corner of each SRA spectrum. The total Hs is shown in the upper right corner. The peak wavenumber is in the upper left corner with the peak frequency. The WW3 spectra are in good agreement with open water SRA spectra for the peak wave direction and frequency. For the landfall case, however, the model could not simulate the peak frequency in a good agreement with SRA observations due to the resolving depth limitations of the model.

IMPACT/APPLICATION

The new movable nested grid ocean model that we have developed makes it feasible to combine realistic basin-scale ocean simulations with mesoscale forecasts for selected regions. In particular, its utility for coupled tropical cyclone-ocean simulations is indispensable. The nested grid model may be utilized as the ocean component of the Navy's coupled ocean atmosphere mesoscale prediction system (COAMPS). The results of our fundamental research on air-sea-land interactions during tropical cyclones have direct application for improving our predictive capabilities.

TRANSITIONS

It is expected that the results of this project will be used by the Navy and the National Weather Service for operational purposes. It is also hoped that the nested-grid ocean model developed during this project will add to the utility of COAMPS and the coupled tropical cyclone-ocean model will be implemented at FNMOC for operational forecasting in the western Pacific.

RELATED PROJECTS

This research is closely related to other research projects funded by ONR that study tropical cyclones. We are working in close collaboration with the GFDL Hurricane Project in developing and testing the new movable nested grid coupled tropical cyclone-ocean model. Implementation and testing of this model at FNMOC will be conducted in collaboration with Dr. Mary Alice Rennick.

REFERENCES

Ginis, I., R.A. Richardson, and L.M. Rothstein, 1998: Design of a multiply - nested primitive equation ocean model. *Mon. Wea. Rev.* 126, 1054-1079.

Rowley C.D. and I. Ginis, 1999: Implementation a mesh movement algorithm into a multiply-nested grid primitive equation ocean model and its application to air-sea interaction studies *Mon. Wea. Rev.*, 127, 1879-1896.

PUBLICATIONS

Shen, W. and I. Ginis, 2001: The impact of ocean coupling on hurricanes during landfall. *Geophys. Res. Let.* Vol. 28 , No. 14, 2839-2842.

Khain A.P., I. Ginis and A. Falkovich, 2001: Interaction of binary tropical cyclones in a coupled tropical cyclone-ocean model. *J. Geophys. Res.,* 105, No. D17, p. 22,337-22,354.

Shen, W., I. Ginis, and R.E. Tuleya, 2001: A numerical investigation of land surface water on landfalling hurricanes. *J. Atmos. Sci.* In press.

Ginis, I., and M.A. Bender, 2001: Implementation of a coupled hurricane-ocean model for operational forecasting at the U.S. National Weather Service. Geophysical Research Abstracts, XXVI EGU General Assembly, Nice, France, 25-30 March.

Ginis, I, R. Richardson, L.M. Rothstein, 2001: Simulations of landfalling hurricanes using a movable nested grid air-sea coupled model. To be submitted.

Moon, Il-Ju, I. Ginis, T. Hara, and E. Walsh, 2001: Hurricane Bonnie Directional Wave Spectra from the WAVEWATCH-III wave model and airborne SRA. To be submitted